DEPARTMENT OF

CIVIL ENGINEERING

Laboratory Report on Preparation of

SPECIMENS FOR DURABILITY OF

SEMI-LIGHTWEIGHT PORTLAND CEMENT/SILICA CONCRETE

IN THE MARINE ENVIRONMENT - PHASE XI

for

CANMET
ENERGY, MINES AND RESOURCES

DSS File No. 67SS.23440-9-9120

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OCTOBER 1990

MICROMEDIA

CONTRACT SERIAL NO. 99120-01-SS
CONTRACT REQUISITION NO. 23440-9-9120
CONTRACTOR: UNIVERSITY OF NEW BRUNSWICK

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31 pp

91-04681/

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Laboratory Report

1. Introduction

The Department of Civil Engineering of the University of New Brunswick was awarded contracts in 1978, 1979, 1980, 1981, 1982, 1985, 1987, 1988 and 1989 by the Department of Supply and Services to prepare large concrete specimens for use by the Department of Energy, Mines and Resources (EMR) in durability studies at the U.S. Corps of Engineers salt water exposure site at Treat Island, Maine. Copies of the corresponding laboratory reports can be obtained from EMR in Ottawa. The first two reports cover specimens containing Type 10 and Type 50 cement with varying percentages of cement replacement with slag and fly ash and with aggregate from the Blagdon Pit. The first report also includes the use of high range water-reducers. The third report covers the use of slag as a replacement for Type 10 and Type 50 cements in semi-lightweight concrete made from expanded shale aggregates. The fourth report covers the use of Type 10 and Type 50 cement in concrete made from sand from the Blagdon Pit and limestone coarse aggregate from the Brookville Pit. The fifth report covers the use of slag and silica fume both as a replacement and as an additive to the normal Portland cement. The sixth report covers the use of steel fibers, fly ash and silica fume as an additive for Type 20 Portland cement when used with low density aggregates made from expanded shale. The seventh report covers the use of high volume of class F fly ash

with normal portland cement. The eighth report covers the use high volume of steel reinforcement in concrete containing normal portland cement in combination with fly ash, slag, or silica fume. The ninth report covers the use of normal portland cement with silica fume in concretes containing lightweight coarse aggregate from sources in New Brunswck, West Germany and New York State. This the tenth report covers the use of high volumes of Class F fly ash with normal portland cement in concretes containing lightweight coarse aggregate from sources in New Brunswick, West Germany and New York state.

The work statement for this contract with associated amendments as well as history for specimens cast are given in Appendix A.

The Canadian Standards Association Standard CAN3-A23.1-M77 on "Concrete Materials and Methods of Concrete Construction" and CAN3-A23.2-M77, "Methods of Test for Concrete" were followed, unless otherwise noted.

2. Materials

(a) Cement

Type 10 cement was supplied by Lafarge Canada Inc. and was delivered in paper bags. All cement was free of lumps and was free flowing. The chemical analysis of the cement, produced at Brookfield, Nova Scotia, is included in Table I.

(b) Fly Ash

A class F fly ash produced in Lingan, Nova Scotia was provided in paper bags. The fly ash was free of lumps and was free flowing. A typical analysis of this fly ash is included in Table I.

(c) Air Entraining Agent

The air entraining agent was Daravair, a neutralized vinsol resin with 20% total solids supplied by W.R. Grace. It was delivered in a 5 gallon metal container.

(d) High Range Water Reducing Agent HRWR Agent

The HRWR agent was a napthalene-based superplasticizer, WRDA 19 manufactured by W.R. Grace. It was delivered in a 5 gallon metal container.

(e) Aggregates

The fine aggregates were obtained from the Blagdon Pit. The coarse aggregate for mix series BA was a lightweight expanded shale from Minto, N.B. and was supplied by Modern Enterprises of Salisbury, N.B. The aggregate was produced using a rotary kiln. Results of tests carried out on the aggregate are given in Table I. For mix series BB an expanded shale aggregate from New York State was supplied by Solite Corporation. For mix series BC Liapor, an expanded clay coarse aggregate from West Germany was provided by the manufacturer.

3. Batching and Mixing

To facilitate handling of the various materials the ingredients were batched in two lots of equal size. The fine and coarse aggregates, and cement, were weighed out in plastic buckets and the fly ash was weighed out in plastic bags.

The mixer was started and one half the fine aggregates, and one half of the air entraining admixture was added. Half the coarse aggregates, one half the cements, and one half the fly ash in that order, were dumped by hand into the mixer. Once half the cements were in the mixer, enough water was then added to bring the mix to about a 25 mm slump. The balance of the constituents were added to the mixer and the slump adjusted to 25 mm by water addition. The HRWR agent was then added to produce a workable mix with a slump of approximately 150 mm.

Air content and plastic unit weight were determined after 5 minutes of continuous mixing. The mix descriptions are given in Table II. When mixing was completed, the concrete was discharged into a wheelbarrow and remixed with a shovel.

Specimens were cast in two layers of equal thickness and consolidated by vibration after each addition of concrete. The cylinders and large prisms were consolidated using a poker-type vibrator, while the smaller prisms were consolidated using the vibrating table.

4. Testing of the Plastic Concrete

Prior to casting the concrete was tested for air content and unit weight. The concrete was consolidated using a vibrating table. The temperature of the concrete was measured using a steel jacketed thermometer. The properties of the plastic concrete can be found in Table III.

5. Testing of the Hardened Concrete

The mass density at 2 days of the 150 ø x 300 mm cylinders and the 76 x 102 x 406 mm prisms were measured and are recorded in Table IV.

Using the unit weight of the fresh concrete and the batch proportions, the mix proportions per cubic meter were calculated and are recorded in Table V. The weights of the fine aggregates are given in a saturated surface-dry moisture condition and the coarse aggregate in surface dry condition after 24 hours of water adsorption.

The compressive strengths at 3, 7, 28, 90 days and 1 year are recorded in Table VI. Table VII lists the modulus of elasticity of the concrete as determined by the ASTM 649 test at 28 days. Specimens of nominal dimension 76 x 102 x 406 mm were tested in flexure according to ASTM C78 at 3, 7, 14, 28, 90 days and 1 year of moist curing and the results are recorded in Table VIII. The freeze-thaw cycling was performed according to ASTM C666 with resonant frequency measurements being carried out

according to ASTM C215. Specimen were conditioned with 21 days moist curing, then 11 days air drying and finally 3 days moist curing prior to the freeze-thaw testing. The relative dynamic modulus of elasticity values from the freeze-thaw testing to 300 cycles are presented in Tables IX.

When all the remaining specimens had been cured for 90 days, the prisms and cylinders were removed from the moist curing room. Compressive strength of the cylinders was tested and the large prisms tested for resonant frequency and pulse velocity. After seven days of air drying they were transported to Treat Island, Maine on June 7, 1990 and installed on the rack at mid tide level.

Freeze thaw testing was continued to 620 cycles. The results are presented in graphical form in figure 1.

APPENDIX A

APPENDIX "A"

WORK STATEMENT

Three series of laboratory concrete mixes shall be made and tested as follows:

Mix Series BA

In this series, four concrete mixes shall be made with type 10 cement from Brookfield N.S. and fly ash from Lingan, N.S. A cement content of 150 Kg/m^3 and a fly ash content of 190 Kg/m^3 (50 lbs/cu yd) shall be used. The sand shall be from the Blagdon pit in New Brunswick. Coarse aggregate shall be expanded shale from the Avon Aggregate plant in Minto. The coarse aggregate shall be soaked for 24 hours prior to mixing and shall then be partially drained prior to mixing. During mixing, water shall be added to produce a slump of approximately 25 mm. After mixing for four minutes sufficient superplasticizer shall be added to produce a slump of 150 mm. Sufficient neutralized vinsol resin shall be added to produce an air content of 5 ± 1% in the plastic concrete. After the concrete has mixed for a total of eight minutes the concrete shall be discharged from the mixer.

From Mix Nos. 1 and 2, one 12 x 12 x 36 in prism and four 6 x 12 in cylinders shall be cast. From Mix No. 3 twelve 6 x 12 in cylinders shall be cast. From Mix No. 4, two 6 x 12 cylinders and 18 75 x 100 x 400 m prisms shall be cast. Before casting, properties of the fresh concrete such as temperature, slump, unit weight and air content shall be determined. Densities of the harden concrete shall be taken at one day. All specimen's shall be moist cured until required for testing or transporting to Treat Island.

Cylinder from Mix No. 1 and 2 shall be tested for compressive strength at 28 and 90 days. Cylinders from Mix No. 3 shall be tested for compressive strength at 3, 7, 28, 90 days and 1 year. Two cylinders shall be tested at 28 days moist curing for Young's static modulus of elasticity. Cylinders from Mix No. 4 shall be tested for compressive strength at 28 days. Three prism shall be tested for flexural strength at 14, 28, 90 days and 1 year. The balance of the 75 x 400 x 100 m prism shall be moist cured for 7 days followed by 7 days air drying and then tested for resistance to freezing and thawing.

At the end of 90 days moist curing the prisms from Mix Nos. 1 and 2 shall be transported to Treat Island.

Mix Series BB

In this series the mixes of Series BA will be repeated using Solite Aggregates.

Mix Series BC

In this series the mixes of Series BA will be repeated using Liapor Aggregates.

Completion of Report: December 31, 1990

1988 CANMET CONTRACT

SERIES	in kg/m³ Cement	Fly Ash	Air	Notation of Casting CANMET	Date
BA 01	150	190	5.0	BA-1	90 02 26
2	150	190	5.0	-2	"
3	150	190	5.0	-3	"
4	150	190	5.0	-4	"
BB 01	150	190	5.0	BB-1	90 02 28
2	150	190	5.0	-2	"
3	150	190	5.0	-3	"
4	150	190	5.0	-4	"
BC 01	150	190	5.0	BC-1	90 02 30
2	150	190	5.0	-2	"
3	150	190	5.0	-3	"
4	150	190	5.0	-4	"

Series	Batch	Specimen Size mm	Specimen Number	Test at Age	Remarks
BA	1	305x305x915	BA01-1		90 days moist
		150ϕx300	-2	28	compression
			-3	28	"
			-4	90	"
			-5	90	"
	2	305x305x915	BA02-1		90 days moist
		150ϕx300	-2	28	"
			-3	28	"
			-4	90	"
			-5	90	"
	3	150ϕx300	BA-3-1	3	compression
			-2	3	"
			-3	3	"
			-4	7	"
			-5	7	compression
			-6	7	"
			-7	28	"
			-8	28	Mod of E, comp.
			-9	28	"
			-10	90	compression
			-11	90	"
			-12	90	"
			-13	1 yr	"
			-14	1 yr	"
			-15	1 yr	"
BA	4	150ϕx300	BA04-1	28	compression
		150ϕx300	-2	28	"
		76x102x406	-3	3	flexural
			-4	3	"
			-5	3	"
			-6	7	"
			-7	7	"
			-8	7	"
			-9	28	"
			-10	28	"
			-11	28	"
			-12	21mc+11ad+3mc	freeze-thaw
			-13	"	"
			-14	"	"
			-15	"	"
			-16	"	"

- continued

Series	Batch	Specimen Size mm	Specimen Number	Test at Age	Remarks
BA	4		BA04-17	"	held
			-18	90	"
			-19	90	"
			-20	90	flexural
			-21	1 yr	"
			-22	1 yr	"
			-23	1 yr	"
			-24		
			-25		
			-26		
			-27		
BB	1	305x305x915	BB01-1		90 days moist
		150ϕx300	-2	28	compression
			-3	28	"
			4	90	"
			5	90	"
BB	2	305x305x915	BB02-1	90	90 days moist
		150ϕx300	-2	28	compression
			-3	28	"
			-4	90	"
			-5	90	"
BB	3	150ϕx300	BB03-1	3	compression
			-2	3	
			-3	3	"
			-4	7	"
			-5	7	"
			-6	7	"
			-7	28	Mod of E, comp
			-8	28	"
			-9	28	compression
			-10	90	"
			-11	90	"
			-12	90	"
			-13	1 yr	"
			-14	1 yr	"
			-15	1 yr	"

Series	Batch	Specimen Size mm	Specimen Number	Test at Age	Remarks
BB	4	150ϕx300	BB04-1	28	compression
		150ϕx300	-2	28	"
		76x102x406	-3	3	flexural
			-4	3	"
			-5	3	"
			-6	7	"
			-7	7	"
			-8	7	"
			-9	28	"
			-10	28	"
			-11	28	"
			-12	21mc+11ad+3mc	freeze-thaw
			-13	"	"
			-14	"	"
			-15	"	"
			-16	"	"
			-17	"	held
			-18	90	"
			-19	90	"
			-20	90	"
			-21	1 yr	"
			-22	1 yr	"
			-23	1 yr	"
			-24		
			-25		
			-26		
			-27		
BC	1	305x305x915	BC01-1		90 moist cured
		150ϕx300	-2	28	compression
			-3	28	"
			-4	90	"
			-5	90	"
BC	2	305x305x915	BC02-1		90 moist cured
		150ϕx300	-2	28	compression
			-3	28	"
			-4	90	"
			-5	90	"

Series	Batch	Specimen Size mm	Specimen Number	Test at Age	Remarks
BC	3	150ϕx300	BC03-1	3	
			-2	3	spare
			-3	3	compression
			-4	7	"
			-5	7	"
			-6	7	"
			-7	28	Mod. of E, comp.
			-8	28	compression
			-9	28	"
			-10	90	"
			-11	90	"
			-12	90	"
			-13	1 yr	"
			-14	1 yr	"
			-15	1 yr	"
BC	4	150ϕx300	BC04-1	28	compression
		150ϕx300	-2	28	"
		76x102x406	-3	3	flexural
			-4	3	"
			-5	3	"
			-6	7	"
			-7	7	"
			-8	7	"
			-9	28	"
			-10	28	"
			-11	28	"
			-12	21mc+1lad+3mc	freeze thaw
			-13	"	"
			-14	"	"
			-15	"	"
			-16	"	"
			-17	"	held
			-18	90	flexural
			-19	90	"
			-20	90	"
			-21	1 yr	"
			-22	1 yr	"
			-23	1 yr	"
			-24		
			-25		
			-26		

TABLE I

Test Results on Materials Used

Physical properties and chemical analyses of cement and Silica Fume Phase XI.-1988

Description of tests	Portland Cement CSA Type 10	Fly Ash
Physical tests - fineness		
Fineness - passing 75 μm, %	-	-
- passing 45 μm, %	88.4	84.0
- blaine, m^2/kg	393	351
Normal consistency, %	-	-
Setting time, min	133	-
Autoclave expansion, %	0.02	-
Physical tests - mortar strength		
Water content, %	-	-
Flow %	-	-
Compressive strength, MPa		
3-day	29.3	-
7-day	34.6	-
28-day	39.5	-
Pozzolanic activity with portland cement, %	-	-
Water requirement, % of control	-	-
Pozzolanic activity with lime, MPa	-	-
Chemical analyses		-
SiO_2, %	19.88	45.2
CaO, %	63.29	1.63
CaO (free), %	0.63	-
Insoluble, %	-	-
LOI, %	2.67	2.66
Al_2O_3, %	5.33	20.7
Fe_2O_3, %	1.92	24.8
SO_3, %	3.89	0.65
MgO, %	1.22	0.97
Na_2O, %	-	0.59
K_2O, %	-	2.40
Alkalies (as Na_2O), %	0.87	-
$CaSO_4$, %	-	-
C_3A, %	-	-

TABLE I (Cont'd)

Sieve Analysis of Fine Aggregate

Sieve Size	% Passing	CSA % Passing
5 mm	100	95 - 100
2.5 mm	89	80 - 100
1.25 mm	71	50 - 90
630 µm	48	25 - 65
315 µm	21	10 - 35
160 µm	6	2 - 10
PAN	0	0

Sieve Analysis of Coarse Aggregate Mix

Sieve Size	% Passing AA	AB	AC	CSA
19 mm	100	100	100	100
12.50 mm	96.7	91.1	93.3	90-100
9.5 mm	45.8	46.6	54.9	40.80
4.75 mm	0.1	0.3	3.9	0.20
PAN	0	0	0	

TABLE II

Concrete Mix Descriptions

Series	Fly Ash (%)	Cement (%)	Cementitious Content (kg/m^3)
BA01	56	44	340
2	56	44	340
3	56	44	340
4	56	44	340
BB01	56	44	340
02	56	44	340
03	56	44	340
04	56	44	340
BC01	56	44	340
02	56	44	340
03	56	44	340
04	56	44	340

TABLE III

Properties of Plastic Concrete

Mix	Date Cast	Air Content (%)	Unit Wt. (kg/m^3)	Slump A	Slump B	Concrete Temp. (°C)
BA01	90 02 26	5.0	1947	28	160	22
02		6.0	1890	25	132	23
03		5.5	1947	35	125	22
04		5.0	1940	35	160	22
BB01	90 02 28	6.0	1840	25	125	23
02		5.5	1848	35	125	23
03		6.0	1819	27	155	22
04		6.0	1826	35	160	22
BC01	90 03 02	5.0	1961	24	130	22
02		4.0	1968	20	170	23
03		4.5	1926	32	128	22
04		5.0	1954	28	150	23

(A) Before HRWR addition

(B) After HRWR addition

TABLE IV

Mass Density at 1 day (Kg/m^3)

Specimen No.	Mass Density	Specimen No.	Mass Density	Specimen No.	Mass Density
		BA04-1	1973	BB01-2	1858
BA01-2	1990	-2	1963	-3	1851
-3	1988	-3	1943[]	-4	1863
-4	1984	-4	1951[]	-5	1869
-5	1968	-5	1955[]	-6	1877
ave	(1983)	-6	1949[]	ave	(1863)
		-7	1946[]	BB02-1	1856
BA02-2	1959	-8	1956[]	-2	1874
-3	1957	-9	1956[]	-3	1866
-4	1938	-10	1954[]	-4	1860
-5	1940	-11	1946[]	ave	(1864)
ave	(1948)	-12	1931[]	BB03-1	1822
		13	1958[]	-2	1814
BA03-1	1943	14	1956[]	-3	1819
-2	1949	15	1960[]	-4	1828
-3	1952	16	1963[]	-5	1835
-4	1942	17	1956[]	-6	1825
-5	1951	18	1969[]	-7	1820
-6	1947	19	1959[]	-8	1829
-7	1947	20	1954[]	-9	1809
-8	1951	21	1964[]	-10	1827
-9	1965	22	1959[]	-11	1834
-10	1957	23	1960[]	-12	1820
-11	1994	24	1960[]	-13	1806
-12	1943	25	1959[]	14	1820
-13	1955	26	1958[]	-15	1827
-14	1954	27	1959[]	ave	(1822)
-15	1946	ave	(1956)		
ave	(1953)				

[] - 76 x 102 x 406 mm prism

(xxxx) - average

TABLE IV

Mass Density at 1 day (Kg/m^3)

Specimen No.	Mass Density	Specimen No.	Mass Density	Specimen No.	Mass Density
BB04-1	1839	BC01-2	1946	BC04-1	1934
-2	1836	-3	1946	-2	1925
-3	1877[]	-4	1944	-3	1954[]
-4	1878[]	-5	1936	-4	1954[]
-5	1873[]	ave	(1943)	-5	1950[]
-6	1875[]			-6	1970[]
-7	1864[]			-7	1962[]
-8	1868[]	BC02-2	1961	-8	1952[]
-9	1869[]	3	1965	-9	1970[]
-10	1863[]	4	1955	-10	1964[]
-11	1852[]	5	1957	-11	1958[]
-12	1854[]	ave	(1960)	-12	1956[]
13	1839[]			-13	1958[]
14	1827[]			-14	1960[]
15	1826[]	BC03-1	1950	-15	1957[]
16	1825[]	-2	1929	-16	1952[]
17	1845[]	-3	1942	-17	1954[]
18	1836[]	-4	1922	-18	1960[]
19	1839[]	-5	1931	-19	1963[]
20	1821[]	-6	1930	-20	1956[]
21	1825[]	-7	1936	-21	1962[]
22	1826[]	-8	1933	-22	1949[]
23	1857[]	-9	1939	-23	1965[]
24	1854[]	-10	1927	-24	1957[]
25	1863[]	-11	1946	-25	1956[]
26	1843[]	-12	1953	-26	1956
27	1844[]	13	1936	-27	1960
ave	(1854)	14	1928	ave	(1958)
		15	1969		
		ave	(1937)		

[] 76 x 102 x 406 mm prism

(xxxx) - average

TABLE V

Mix Proportions in Kg/m^3 (unless otherwise noted)

Mix	Fly Ash	Cement	Water	F.A.	C.A.	AEA ml/m^3	HRWR ml/m^3
BA-1	192.1	152.0	130.2	772.3	698.5	190	1813
BA-2	186.0	148.0	129.1	749.0	677.1	184	959
BA-3	192.0	152.5	132.4	771.0	698.0	189	1319
BA-4	191.3	151.9	131.9	768.2	698.5	189	1314
BB-1	191.5	152.8	135.3	752.5	606.7	185	2092
BB-2	192.2	153.5	135.7	755.5	609.2	178	1858
BB-3	189.0	150.9	136.4	742.8	598.9	151	1588
BB-4	189.7	151.5	137.0	745.6	601.2	167	1674
BC-1	192.2	153.5	131.1	757.0	726.1	131	1615
BC-2	191.8	153.1	142.0	755.9	724.6	145	1612
BC-3	183.7	146.1	151.1	736.5	708.8	128	1837
BC-4	190.8	152.3	137.2	751.5	720.9	144	1603

Note: F.A. and C.A. at SSD. Moisture Content

Based on Oven Dry Weight = 100%

Mix Series	C.A. moisture content at SSD
BA	6.49 %
BB	11.07
BC	12.38

TABLE VI
Compressive Strength

Cylinder No.	Strength in MPa				
Moist cured	3 days	7 days	28 days	90 days	1 yr
BA01-2			24.99		
-3			26.46		
-4				36.7	
-5				36.7	
ave			(25.73)	(36.7)	
BA02-2			21.46		
-3			21.82		
-4				33.53	
-5				32.92	
ave			(21.64)	(33.23)	
BA03-1	8.47				
-2	8.41				
-3	8.47				
-4		10.05			
-5		9.97			
-6		10.12			
-7			24.57		
-8			25.18		
-9			25.60		
-10					
-11				37.31	
-12				35.85	
-13				36.46	
-14					
-15					
ave	(8.45)	(10.05)	(25.12)	(36.54)	
BA04-1			27.56		
-2			26.58		
ave			(27.07)		

TABLE VI - continued

Compressive Strength

Cylinder No.	Strength in MPa				
Moist cured	3 days	7 days	28 days	90 days	1 yr
BB01-2			20.12		
-3			20.36		
-4				28.77	
-5				31.70	
ave			(20.24)		
BB02-2			20.70		
-3			20.30		
-4				30.73	
ave			(20.50)		
BB03-1	5.06				
-2	4.99				
-3	5.08				
-4					
-5		8.47			
-5		8.41			
-7		8.47	15.61		
-8			15.85		
-9			16.20		
-10					
-11				24.99	
-12				24.26	
-13				23.78	
-14					
-15					
-16					
-17					
ave	(5.04)	(8.45)	(15.88)	(28.77)	
BB04-1			16.95		
-2			15.12		
ave			(16.04)		

TABLE VI
Compressive Strength

Cylinder No.	Strength in MPa				
Moist cured	3 days	7 days	28 days	90 days	1 yr
BC01-2			31.70		
-3			30.66		
-4				42.80	
-5				44.26	
ave			(31.18)		
BC02-2			34.99		
-3			33.53		
-4				47.80	
-5				47.80	
ave			(34.26)		
BC03-1	8.10				
-2	7.73				
-3	8.25				
-4		11.95			
-5		12.31			
-6		12.13			
-7			23.17		
-8			23.17		
-9			23.78		
-10				34.63	
-11				34.63	
-12				35.50	
-13					
-14					
-15					
ave	(8.03)	(12.13)	(23.37)	(34.95)	
BC04-1			28.59		
-2			28.65		
ave			(28.62)		

TABLE VII

Modulus of Elasticity at 28 day

Specimen No.	Modulus (MPa)
BA3-7	16,833
BA3-8	16,534
ave	(16,683)
BB3-7	14,637
BB3-8	15,256
ave	(14,946)
BC3-7	17,676
BC3-8	17,889
ave	(17,782)

TABLE VIII
Flexural Strength

Prism No.	Strength in MPa				
Moist cured	3 days	7 days	28 days	90 days	1 yr
BA04-3	2.14				
-4	2.02				
-5	2.04				
-6		2.48			
-7		2.82			
-8		2.42			
-9			4.30		
-10			4.28		
-11			4.56		
-12				4.64	
-13				4.68	
-14				4.80	
-21					
-22					
-23					
-24					
-25					
-26					
-27					
ave	(2.07)	(2.57)	(4.38)	(4.64)	

TABLE VIII (cont'd)
Flexural Strength

Prism No.	Strength in MPa				
Moistured	3 days	7 days	28 days	90 days	1 yr
BC04-3	1.72				
-4	1.84				
-5	1.76				
-6		1.80			
-7		1.94			
-8		2.04			
-9			3.06		
-10			3.48		
-11			3.40		
-12				5.52	
-13				5.36	
-14				5.48	
-21					
-22					
-23					
-24					
-25					
-26					
-27					
ave	(1.77)	(1.93)	(3.31)	(5.45)	

TABLE VIII (cont'd)

Flexural Strength

Prism No.	Strength in MPa				
Moisture	3 days	7 days	28 days	90 days	1 yr
BB04-3	0.42				
-4	1.42				
-5	1.32				
-6		1.72			
-7		1.84			
-8		1.76			
-9			2.60		
-10			2.76		
-11			2.74		
-12				3.58	
-13				3.52	
-14				4.38	
-21					
-22					
-23					
-24					
-25					
-26					
-27					
Ave	(1.05)	(1.77)	(2.70)	(3.83)	

TABLE IX

Relative Dynamic Modulus of Elasticity for Freeze-Thaw Specimens (Resonant Frequency)

	0	36	72	103	138	176	212	248	292
BA4-12	100.0	100.8	99.7	100.0	99.1	98.7	98.1	97.6	97.3
BA4113	100.0	100.1	100.3	99.7	100.3	99.7	99.2	98.8	98.3
BA4-14	100.0	99.2	99.5	99.2	99.5	98.8	98.7	98.3	97.4
BA4-15	100.0	101.1	99.6	99.6	99.5	99.2	98.9	98.4	97.4
							Durability Factor =		97.6
BB4-12	100.0	99.4	99.6	99.7	99.6	100.3	99.6	98.8	98.4
BB4-13	100.0	100.7	100.3	100.9	100.6	100.1	100.0	99.6	99.6
BB4-14	100.0	99.9	99.6	99.4	99.6	100.1	98.7	98.5	98.4
BB4-15	100.0	100.3	99.7	100.0	100.0	100.0	100.0	99.6	99.3
							Durability Factor =		98.9
BC4-12	100.0	99.9	99.7	99.5	98.6	97.7	96.4	94.5	92.2
BC4-13	100.0	100.3	100.4	100.3	99.7	98.3	97.5	96.1	94.5
BC4-14	100.0	99.9	100.0	99.9	99.5	98.7	97.5	96.5	95.0
BC4-15	100.0	100.1	100.4	100.6	100.0	99.4	98.6	98.3	97.2
							Durability Factor =		94.7

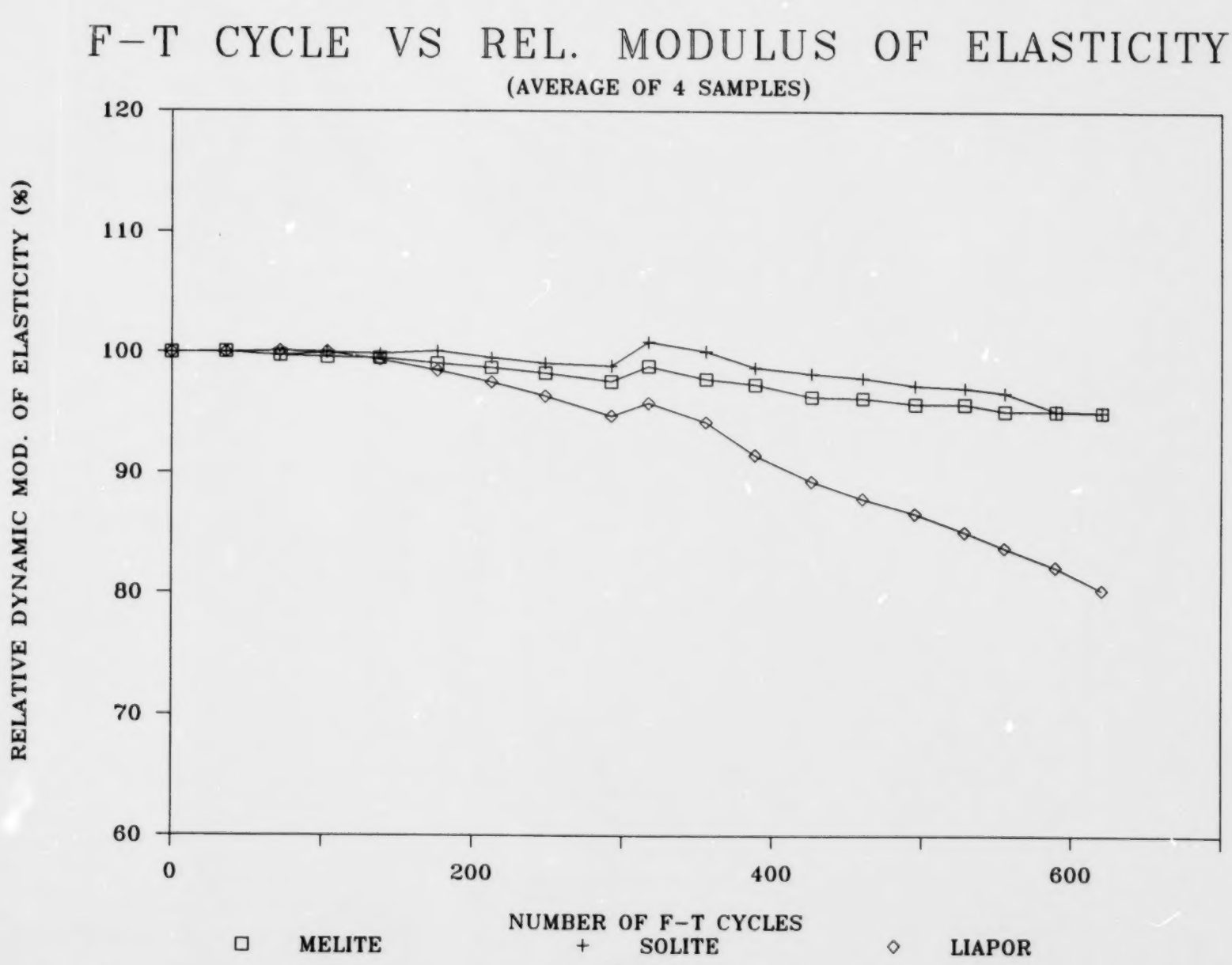
F-T CYCLE VS REL. MODULUS OF ELASTICITY
(AVERAGE OF 4 SAMPLES)
RELATIVE DYNAMIC MOD. OF ELASTICITY (%)
120
110
100
90
80
70
60
0
200
400
600
NUMBER OF F-T CYCLES
MELITE
SOLITE
LIAPOR

Figure 1